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DTOS Rec'd DTCTTC 08 MAR 2005

## SPECIFICATION

### REMOTE-ACCESS VPN MEDIATING METHOD AND APPARATUS

#### 5 TECHNICAL FIELD

[0001] The present invention relates to techniques by which, of pieces of information for implementation of a remote-access VPN by an arbitrary tunneling protocol, such as IPsec (IPsecurity Protocol) or L2TP (Layer2 Tunneling Protocol), a global IP address of a VPN client unit, a global IP  
10 address of a VPN gateway unit, and mutual authentication information to be used for authentication between the VPN client unit and the VPN gateway unit are shared in security between them.

#### BACKGROUND ART

[0002] A virtual closed network that is built up on the Internet is commonly  
15 called a Virtual Private Network (hereinafter abbreviated as VPN). The VPN is built using such a tunneling protocol as IPsec, L2TP or the like, and it is used for accessing a resource in a local area network (LAN) from a moving client via the Internet, or for interconnecting multiple physically dispersed local area networks via the Internet. In the case of authorizing a remote user  
20 to access a remote-access VPN, the following settings are required of both of the VPN client to access and the VPN gateway to be accessed.

[0003] VPN client unit:

- IP address (global) of a VPN gateway unit
- Mutual authentication information between the VPN gateway unit  
25 and a VPN client unit
- Private IP address of the VPN client unit
- Private IP addresses of a router and a name server (such as

DNS, WINS) of an internal network of VPN (in the case of static setting on the part of the VPN client)

VPN gateway unit:

- Mutual authentication information between the VPN gateway unit and the VPN client unit
- Private IP address to be delivered to an authenticated VPN client unit and private IP addresses of the router and the name server in VPN (in the case of dynamic setting/posting on the part of VPN client)

In general, these settings affect security, and hence they must be done with security and with reliability, which places a heavy load not only on a VPN client unit user but also on a VPN administrator. And, when users accessible to this VPN change one after another, the burden of user management also becomes tremendous. Further, when a user accesses two or more VPNs, an authentication method, authentication information, and an IC card or similar authentication device for retaining them may sometimes differ for each VPN to be connected; the management therefor becomes a serious burden.

[0004] Occasionally the situation arises where the VPN client unit wants to temporarily exercise its granted VPN access authority in another VPN client unit. Further, in the case where the VPN client unit (A) is inside an NAT (Network Address Translation) segment or where it is a portable miniature device of severely limited power requirements, it is not proper to directly establish an encrypted channel for communication with the VPN gateway unit. In this instance, it is typical that another VPN client unit (D), which possesses the function of gateway from the NAT segment concerned to the Internet, takes the charge of establishing a tunnel to the VPN gateway. In this case, access control needs to be effected for the VPN client unit (A), not for the

VPN client unit (D). Thus, when the VPN client unit granted the access authority differs from the VPN client unit from which the tunnel starts, a mechanism for delegating authority is indispensable.

[0005] Moreover, depending on the property of the service offered by VPN,

5 the VPN client unit user may sometimes want to avoid divulgence of personally identifiable information to the VPN service provider. On the other hand, the VPN service provider also wants, in many cases, to devote themselves to offering their primary services by outsourcing complicated operations such as handling client authentication information or similar  
10 personal information and management of members' admission and withdrawal. In this instance, the VPN service provider makes the outsourcer perform user authentication and verification of the access authority and introduce only valid users to the VPN service provider.

Secure distribution of the common key can be achieved by various  
15 methods (see patent documents 1 and 2, for instance). The method set forth in patent document 1 is a method that exchanges the common key between two or more communication units connected to a local area network; this method exchanges the common key via the gateway unit equipped with a DHC server function. More specifically, at the time of connecting the  
20 communication units to the local area network, the common key is exchanged simultaneously with acquisition of their IP addresses by DHCP. This permits exchanging the common key for encrypting communications in the local area network.

[0006] The method described in patent document 2 is a method by which, in  
25 the communication between the VPN client unit connected to the Internet and the communication unit connected to the local area network placed under the management of the VPN gateway unit, a common key is exchanged between

the VPN client unit and the VPN gateway unit, and another common key is exchanged between the VPN gateway unit and the communication unit.

This permits implementation of encrypted communication between the VPN client unit and the communication unit connected to the local area network

5 without the need for a key exchange by an IKE or similar key exchange scheme between the VPN client unit and the communication unit connected to the local area network.

[0007] However, the method of patent document 1 limits the key distribution range to the local area network and the method of patent document 2 calls for  
10 pre-exchanging of the common key between the VPN client unit and the VPN gateway unit, and for these reasons, the management operations become complicated, for example, in the case where the admission and withdrawal of members of a society occur frequently. And either method does not provide a function of delegating access control to a third party and a function of  
15 allowing the VPN client unit to delegate encrypted communication processing to another reliable VPN client unit for access to the VPN gateway to which the VPN client unit is authorized to be connected. There are proposed various methods by which the VPN gateway side dynamically sets/posts the configuration management information, such as the private IP address to be  
20 delivered to the authenticated VPN client unit, private addresses of a router and a name server in VPN (see, for example, patent document 3, patent document 4, non-patent document 1, non-patent document 2, and non-patent document 3).

According to patent document 3, a management unit for management  
25 of setting information is provided, which logs in to a communication unit by presenting thereto its IP address and a log-in password to transfer the setting information. With this method, configuration management information,

such as the private IP address and so on, can be distributed as setting information to the VPN client unit from the management unit corresponding to the VPN gateway unit. However, this method does not authenticate the VPN client unit that is a receiver—this poses a danger of impersonation attack by masquerading of the IP address and intermediary attack. Further, no mention is made of how the management unit performs authentication/access control when the VPN client unit issues a request for acquisition of the configuration management information.

[0008] Patent document 4, non-patent document 1, non-patent document 2 and non-patent document 3 all set forth methods of dynamic setting/posting of the configuration management information by such tunneling protocols as IPsec, PPP, L2TP, and the like.

The present invention also makes an assumption that the function corresponding to the above-mentioned dynamic setting/posting is performed in the set-up phase of various tunnel protocols between the VPN client unit and the VPN gateway unit. But, according to the conventional systems, user authentication or access control and the dynamic setting/posting of the above-mentioned configuration management information are carried out as a single, integral operation at the time of tunnel set-up; in contrast thereto, according to the present invention, the user authentication and the access control are performed in a mediating apparatus to allow the VPN client unit and the VPN gateway unit to share a common secret, which is used to set up a tunnel between the VPN client unit and the VPN gateway unit, and then the configuration management information about the tunnel is dynamically set/posted from the VPN gateway unit. Besides, the VPN client unit A delegates the tunnel protocol processing for encrypted communication to another reliable VPN client unit D, by which it is possible to make a check of

the access authority in the mediating apparatus for the source unit B. According to management convenience, part of the configuration management information on the tunnel, information for routing to the tunnel, or similar information about network operation, may be sent from the mediating apparatus to the VPN client unit. In this instance, the configuration management information sent from the mediating apparatus is set before or after tunnel setup in accordance with the kind of information.

As an authentication and a certificate issuing method using a public key, there is proposed an SPKI (Simple Public Key Infrastructure) scheme (for example, non-patent document 4, and non-patent document 5), but it is not clear how to apply the scheme to the remote-access VPN.

Patent document 1: Japanese Patent Application Kokai Publication No.2001-292135

Patent document 2: Japanese Patent Application Kokai Publication No.2002-271309

Patent document 3: Japanese Patent Application Kokai Publication No.2003-18163

Patent document 4: Japanese Patent Application Kokai Publication No.2001-160828

Non-patent document 1: B. Patel, B. Aboba, S. Kelly, V. Gupta, "Dynamic Host Configuration Protocol (DHCPv4) Configuration of IPsec Tunnel Model," [online], published January, 2003. RFC3456, Internet Engineering Task Force, [Retrieved March 17, 2003], Internet <URL:<http://www.ietf.org/rfc/rfc3456.txt>>

Non-patent document 2: IPCP (RFC-1332)

Non-patent document 3: EAP (RFC-2284)

Non-patent document 4: C. Ellison, B. Frantz, B. Lampson, R. Rivest, B.

Thomas, T. Ylonen, "SPKI Certificate Theory," [online], published September 1999, RFC2693, Internet Engineering Task Force, Internet

<URL:http://www.ietf.org/rfc/rfc2693.txt>

Non-patent document 5; C. Ellison, B. Frantz, B. Lampson, R. Rivest, B.

- 5 Thomas, T. Ylonen, "Simple Public Key Infrastructure  
<draft-ietf-spki-cert-structure-0.6.txt>" [online], published July 26, 1999,  
Internet Engineering Task Force,  
Internet<URL:http://world.std.com/~cme/spki.txt>

#### DISCLOSRE OF THE INVENTION

#### 10 PROBLEM TO BE SOLVED BY THE INVENTION

- [0009] In view of the above-described problems, the present invention has been made by which, of pieces of information to be used for implementing a remote-access VPN by an arbitrary tunneling protocol, such as IPsec and L2TP, in an IP network, a global IP address of a VPN client unit, a global IP  
15 address of a VPN gateway unit, a private IP address of an arbitrary communication unit in a local area network placed under the control of the VPN gateway unit, and a common key to be used for authentication in an IKE phase 1 between the VPN client unit and the VPN gateway unit can be shared therebetween with security. Further, the invention is to enable  
20 communication for authentication in remote-access VPN without leakage of user's personal information to the other party.

#### MEANS FOR SOLVING THE PROBLEM

- [0010] According to the present invention, there is provided a remote-access VPN mediating method in a system wherein: a virtual private network,  
25 hereinafter referred to as VPN, client units and a VPN gateway unit are connected to an IP network; communication units are connected to a local area network placed under the management of the VPN gateway unit; and a

remote-access VPN by a tunneling protocol is implemented between an arbitrary one of VPN client units and the VPN gateway unit connected to said IP network and an arbitrary one of the communication units connected to the local area network placed under the management of the VPN gateway unit;

5 said method comprising the steps of:

(a) sending an access control list containing information indicative of a private IP address assigned to said communication unit to a mediating apparatus on said IP network from said VPN gateway unit;

10 (b) storing said access control list by said mediating apparatus in correspondence to said VPN gateway unit;

(c) retrieving an IP private address corresponding to said VPN gateway unit in response to a request from said VPN client unit, acquiring the private IP address of the corresponding communication unit from said access control list, sending the acquired private IP address to said VPN client unit, 15 sending the IP address of said VPN client unit to said VPN gateway unit, generating mutual authentication information for setting up an authenticated encrypted tunnel between said client VPN unit and said gateway unit, and sending said mutual authentication information to both of said VPN client unit and said gateway unit; and

20 (d) setting up said authenticated encrypted tunnel between said VPN client unit and said gateway unit by use of said mutual authentication information, and implementing remote access through said encrypted tunnel by use of the private IP address of said communication unit.

[0011] According to the present invention, there is provided a remote-access 25 VPN mediating apparatus which is built on an IP network to implement a remote-access VPN in a system wherein: VPN client units and a VPN gateway unit are connected to the IP network; communication units are

connected to a local area network placed under the management of said VPN gateway unit; and a remote-access VPN by a tunneling protocol is implemented between an arbitrary one of said VPN client units and said VPN gateway unit connected to said IP network and an arbitrary one of said communication units connected to said local area network placed under the management of said VPN gateway unit; said apparatus comprising:

ACL storage means for storing an access control list, hereinafter referred to as ACL, sent from said VPN gateway unit and containing information indicative of the private IP address assigned to said

10 communication unit;

authentication/access authorization control means for authenticating said VPN client unit and said gateway unit, and for executing access authorization control;

IP address acquiring means for referring to said access control list to acquire the private IP address assigned to said communication unit, and for searching a domain name server to acquire the IP address assigned to said VPN gateway unit;

authentication information generating means for generating mutual authentication information for setting up an encrypted tunnel between said VPN client unit and said VPN gateway unit; and

communication means for sending the IP address of said VPN gateway unit, the private IP address of said communication unit and said mutual authentication information to said VPN client unit, and for sending the IP address of said PN client unit and said mutual authentication information to said VPN gateway unit.

#### EFFECT OF THE INVENTION

[0012] The present invention produces such effects as described below. A

first effect resides in that, of pieces of information to be used for implementing a remote-access VPN by an arbitrary tunneling protocol, such as IPsec and L2TP, in an IP network, a global IP address of a VPN client unit, a global IP address of a VPN gateway unit, a private IP address of an arbitrary communication unit in a local area network placed under the control of the VPN gateway unit, and a common key or common secret (hereinafter referred to as mutual authentication information) necessary for mutual authentication for setting up an encrypted tunnel between the VPN client unit and the VPN gateway unit can be shared therebetween with security. The reason for this is secure management of the private IP address in the mediating apparatus and secure distribution of the private IP address and the mutual authentication information.

[0013] Specifically speaking, in the case of entry of the private IP address thereinto, the mediating apparatus authenticates the VPN gateway unit and, only when the authentication is successful, encrypts the communication channel, and receives the private IP address over the encrypted communication channel. In the case of retrieval of the private IP address, the mediating apparatus: authenticates the VPN client unit; and, only when the authentication is successful, effects access authorization control by use of the public key of the VPN client unit; and, only when the access authorization control is successful, acquires the global IP address of the VPN gateway unit from the domain name server; encrypts the communication channel between the mediating apparatus and the VPN client unit; sends the global IP address of the VPN gateway unit, the private IP address of the communication unit, and the mutual authentication information to the VPN client unit over the encrypted communication channel; and encrypts the communication channel between the mediating apparatus and the VPN gateway unit; sends the global

IP address of the VPN client unit, the mutual authentication information, and attribute information of the VPN client unit to the VPN gateway unit.

[0014] A second effect is to provide means by which communication in the authentication for remote-access VPN can be conducted without leakage of user's personal information to the other party of communication. The reason for this is that in the case of authentication by the PKI scheme, a common key certificate containing personal information is sent to the mediating apparatus for authentication in place of the other party of communication. Another reason resides in that in the case of authentication by the SPLI scheme, the format of any certificate can be so defined as not to contain personal information. On the other hand, the mediating apparatus may be associated with: a function of sending the attribute information accompanying the authentication result to the VPN gateway unit to select VLAN for accommodating the VPN client unit concerned; a function of changing packet filtering setting of the VPN gateway unit concerned; and a function of adding the attribute information concerned to an inverted dictionary of DNS in VPN in the entry corresponding to the private IP address of the VPN client unit.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0015] [Fig. 1] is a diagram illustrating an example of a system configuration in a first embodiment of the present invention.

[Fig. 2] is a diagram for explaining the general outline of the operation of the first embodiment of the present invention.

[Fig. 3] is a diagram showing the functional configuration of mediating an apparatus (S) 104 of the present invention.

[Fig. 4]A is a table showing the correspondence between ACL and hash values, and B is a diagram showing an example of an ACL entry in Fig. 4A.

[Fig. 5] is a diagram showing access control ACL storage means in the first embodiment of the present invention.

[Fig. 6] is a diagram showing the procedure for sending an IP address and a common key in the first embodiment of the present invention.

5 [Fig. 7] is a detailed flowchart showing an IP address acquiring procedure and a common key generating procedure in the mediating apparatus in the first embodiment of the present invention.

[Fig. 8] is a diagram showing an example of the access control list ACL in the first embodiment.

10 [Fig. 9] is a diagram showing an example of data TAG in the first embodiment of the present invention.

[Fig. 10] is a diagram showing an example of calculated result data DATA in the first embodiment of the present invention.

[Fig. 11] is a diagram showing an example of a certificate in the first  
15 embodiment of the present invention. Its program can be distributed via a network.

[Fig. 12] is a diagram illustrating a system configuration in a second embodiment of the present invention.

[Fig. 13] is a diagram for explaining the general outline of the  
20 operation of the second embodiment of the present invention.

[Fig. 14] is a diagram showing access control ACL storage means in the second embodiment of the present invention.

[Fig. 15] is a detailed flowchart showing access control list ACL storage procedure in the mediating apparatus in the second embodiment of the  
25 present invention.

[Fig. 16] is a diagram showing IP address and common key distribution procedures in the second embodiment of the present invention.

[Fig. 17] is a detailed flowchart showing an IP address acquiring procedure and a common key generating procedure in the mediating apparatus in the second embodiment of the present invention.

[Fig. 18] is a diagram illustrating an embodiment of VPN client unit in  
5 a third embodiment of the present invention.

[Fig. 19] is a diagram illustrating the entire configuration of a network in which VPN gateway unit in a fourth embodiment of the present invention is used.

[Fig. 20] is a diagram showing an example of an access control list for  
10 use in the fourth embodiment.

[Fig. 21] is a diagram illustrating an example of the functional configuration of the VPN gateway unit for use in the fourth embodiment.

#### BEST MODE FOR CARRYING OUT THE INVENTION

[0016] A detailed description will hereinbelow be given, with reference to the  
15 accompanying drawings, of embodiments of the present invention.

#### EMBODIMENT 1

This is an embodiment in which a mediating apparatus authenticates a VPN client unit and a VPN gateway unit by an SPKI (Simple Public Key Infrastructure) scheme, and the VPN client unit issues a certificate for the  
20 delegation of authority. This SPKI scheme does not require an authentication station.

Fig. 1 illustrates a general system configuration of this embodiment. In Fig. 1 a VPN client unit (A) 101, a VPN client unit (D) 102, a VPN gateway unit (B) 103, a mediating apparatus (S) 104, and a domain name  
25 server (DNS) 105 are each connected to a Wide Area Network (WAN) 100 under IP (Internet Protocol). A communication unit (C) 111 is connected to a Local Area Network (LAN) 110 that uses the VPN gateway unit (B) 103 as

a gateway unit. On WAN there may also be provided a VPN gateway control unit (M) 112 that has the authority of management of an access control list for the VPN gateway unit (B) 103.

[0017] Fig. 2 is a diagram for explaining the operation of the entire system depicted in Fig. 1. The thick lines indicate VPNs in an IPsec tunnel mode.

Now, let the host name of the VPN client unit (A) 101 be represented by a public key PUBLICKEY\_A (or its hash value HASH\_A) and its IP address by IPADDRESS\_A. Let the host name of the VPN client unit (D) 102 be represented by a public key PUBLICKEY\_D (or its hash value HASH\_D) and its IP address by IPADDRESS\_D. And, let the host name of the VPN gateway unit (B) 103 be represented by a public key PUBLICKEY\_B (or its hash value HASH\_B) and its IP address by IPADDRESS\_B. Thus the VPN client unit and the VPN gateway unit can be identified by their public keys (or their hash values). Let the private IP address of the communication unit (C) 111 be represented by IPADDRESS\_C.

[0018] The IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, and the IP address IPADDRESS\_D assigned to the VPN client unit (D) 102 are all unique in the IP network (WAN) 100, and they are dynamically assigned by arbitrary means. The public key PUBLICKEY\_B and the IP address IPADDRESS\_B of the VPN gateway unit (B) 103 are uniquely associated with each other and placed under the management of the domain name server (DNS) 105. The private IP address IPADDRESS\_C assigned to the communication unit 111 is unique in the local area network (LAN) 110, and it is dynamically assigned by arbitrary means.

[0019] The VPN client unit (A) 101, the VPN client unit (D) 102, the VPN

gateway unit (B) 103, and the mediating apparatus (S) 104 each have means for encrypting a channel by an IPsec transport mode or IPsec tunnel mode.

The VPN client unit (A) 101 retains, together with the public key

PUBLICKEY\_A, a private key PRIVATEKEY\_A that pairs with the public

5 key PUBLICKEY\_A. The VPN gateway unit (B) 103 retains, together with

the public key PUBLICKEY\_B, a private key PRIVATEKEY\_B that pairs

with the public key PUBLICKEY\_B. The VPN client unit (D) 102 retains,

together with the public key PUBLICKEY\_D, a private key

PRIVATEKEY\_A that pairs with the public key PUBLICKEY\_D. The VPN

10 gateway unit (B) 103 retains an Access Control List (ACL) that describes conditions necessary for access to the communication unit 111 on the local area network 110.

[0020] Fig. 8 shows an example of the access control list (ACL) in this

embodiment. The grammar of the access control list (ACL) is defined in the

15 afore-mentioned non-patent documents 4 and 5 concerning SPKI. In the Fig.

8 example, it is specified that the hash value of the public key of an access

subject by a hash sha 1 written in a subject field (subject) has HASH\_A—this

indicates that the subject is allowed to access the communication unit 111 that

has the private IP address IPADDRESS\_C on the local area network 110

20 connected to the VPN gateway unit 103 having a sha 1 hash value HASH\_A

described in a tag field (tag). The field of attribute information

“ATTRIBUTE\_A” is provided as an additional function, by which, for

example, the range of private addresses to be assigned is changed with a

“non-paying user” and a “paying user,” thereby permitting changing of the

25 accessible server by packet filtering in the VPN gateway unit (B) 103, or

changing of the service by a Web server to a client in accordance with the

source address. The field “validity” indicates the period for which this entry

of ACL is valid. The field “propagate” indicates authorization of the delegation of authority of the access subject, but since no delegation of authority is made in this embodiment, this field is used as a mere data value for authentication, together with other fields.

- 5 [0021] The mediating apparatus (S) 104 comprises, as shown in Fig. 3, access control list (ACL) storage means 1041, authentication/access authorization control means 1042, IP address acquiring means 1043, key generating means 1044 serving as mutual authentication information generating means, communication means 1045 having encryption means 1045e, and operation
- 10 control means 1046 for controlling operations of these means. The IP address acquiring means 1043 presents the public key PUBLICKEY\_B of the VPN gateway unit (B) 103 to the domain name server (DNS) 105 and acquires therefrom the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103. The ACL storage means 1041 stores, as a table, the
- 15 access control list (ACL) entered from the VPN gateway unit (B) 103. The authentication/access authorization control means 1042 uses the SPKI scheme to authenticate the VPN client unit (A) 101 and the VPN gateway unit (B) 103 by the SPKI scheme and/or execute access authorization control. The communication unit 1045 has the encryption means 1045e, by which the
- 20 communication channel is encrypted to provide security for transmission and reception of information. The key generating means 104, which serves as mutual authentication information generating means, generates common keys KEY\_AB and KEY\_DB as mutual authentication information described later on.
- 25 [0022] The above-mentioned address acquiring means 1043 retrieves the IP address IPADDRESS\_B from the public key PUBLICKEY\_B by a common IP address retrieval scheme (name resolution scheme). The

above-mentioned ACL storage means 1041 manages the public key  
 PUBLICKEY\_B and the access control list (ACL) in association with each  
 other, for example, in the form of a table 1041T as depicted in Fig. 4A. In  
 Fig. 1 there is shown only one VPN gateway unit, but in fact, multiple VPN  
 5 units have their local area networks connected to WAN 100; and while only  
 one communication unit is shown in Fig. 1, multiple communication units are  
 supposed to be connected to each local area network. In Fig. 4A access  
 control lists are entered in correspondence to hash values of public keys of the  
 respective VPN gateway unit.

- 10 [0023] Each access control list ACL in the ACL table 1041, for example, ACL  
 1, is shown as Table ACL1 in Fig. 4B, wherein hash values of public keys  
 unique to subjects, for example, VPN client units, which access the respective  
 communication units on the local area networks to which the access subjects  
 belong, are given in correspondence to private IP addresses of the respective  
 15 communication units. In the example on the first line in the table of Fig. 4B  
 it is indicated that the VPN client unit of the hash value HASH\_A is  
 authorized to access the communication unit of the private IP address  
 IPADDRESS\_C1. In practice, it is described in the form shown in Fig. 8  
 referred to previously. The access subject in the access control list ACL  
 20 provided for each unit to be accessed is not limited specifically to the hash  
 value of the public key as in the examples of Figs. 4A and 8, but it may also  
 be various other identification such as an employee number, membership  
 number, or number certifying that the access subject is an employee of some  
 company, member of some group, or qualified person.
- 25 [0024] The above-mentioned authentication/access authorization control  
 means 1042 authenticates the VPN client unit (A) 101, the VPN gateway unit  
 (B) 103, and the VPN client unit (D) 102 by the SPKI scheme. Specifically

speaking, upon input thereto of a signature SIG\_A by a private key PRIVATEKEY\_A and a public key PUBLICKEY\_A of the VPN client (A), the authentication/access authorization control means uses the public key to verify the signature SIG\_A, thereby proving the identity of the VPN client (A) having the private key PRIVATEKEY\_A corresponding to the public key PUBLICKEY\_A. By inputting thereto a signature SIG\_B by a private key PRIVATEKEY\_B and a public key PUBLICKEY\_B and verifying the signature SIG\_B, the authentication/access authorization control means proves the identity of the VPN gateway unit (B) having the private key PRIVATEKEY\_B. Similarly, by inputting thereto a signature SIG\_D by a private key PRIVATEKEY\_D and a public key PUBLICKEY\_D and verifying the signature SIG\_D, the authentication/access authorization control means proves the identity of the VPN client (D) having the private key PRIVATEKEY\_D.

[0025] The above-mentioned authentication/access authorization control means 1042 controls the authorization of access of the VPN client unit (A) 101 and the VPN client unit (C) 102 to the VPN gateway unit (B) 103 by the SPKI scheme. In the case of controlling the authorization of access of the VPN client unit (A) 101 to the VPN gateway unit (B) 103, the authentication/access authorization control means inputs thereto a DNS query QUERY, a signature SIG\_A and an access control list (ACL) for retrieving the IP address IPADDRESS\_B, uses them as data values to execute calculations based on the 5-tuple reduction operation rules and/or 4-tuple reduction operation rules defined in the SPKI-related non-patent documents 4 and 5, and outputs the operation results. In the case of controlling the authorization of access of the VPN client unit (D) 102 to the VPN gateway unit (B) 103, the authentication/access authorization control means inputs thereto a DNS query

QUERY, a signature SIG\_D, a certificate CERT defined in the SPKI-related non-patent documents 4 and 5, and an access control list (ACL), then executes calculations based on the 5-tuple reduction operation rules and/or the 4-tuple reduction operation rule defined in the SPKI-related non-patent documents 4 and 5, and outputs the operation results. The operation results will be described concretely later on with reference to Fig. 10.

[0026] The above-mentioned key generating means 1044 generates a common key KEY\_AB that is used for authentication in an IKE phase 1 between the VPN client unit (A) 101 and the VPN gateway unit (B) 103, or KEY\_DB that is used for authentication in an IKE phase 1 between the VPN client unit (D) 102 and the VPN gateway unit (B) 103.

The VPN client unit (A) 101 possesses a function of issuing a authority delegation certificate CERT to the VPN client unit (D) 102 by. In the SPKI-related non-patent documents 4 and 5, there are defined grammar for two kinds of certificates, i.e., Authorization Certificate and Name Certificate. In this embodiment the certificate CERT is limited only to the authorization certificate for the sake of brevity.

[0027] Fig. 11 shows a concrete example of the certificate CERT in this embodiment. According to the SPKI-related non-patent documents 4 and 5, the authorization certificate is data signed with a private key of the issuer which data will hereinafter be referred to as certificate information INFO), the data being composed of: an issuer field that defines the public key uniquely corresponding to a private key of the issuer, or the hash value of the public key; a subject field that defines the public key uniquely corresponding to a private key of the authorizer, i.e., the VPN client (D) in this case, or the hash value of the public key; a tag field containing a character string that defines the contents of authorization; a delegation field containing a character string

that defines whether or not to authorize the delegation of authority; and a validity field containing a character string that defines the validity interval of the authorization certificate.

[0028] Based on this definition, the value of the issuer field in the certificate information INFO of the certificate CERT in this embodiment is defined as the hash value HASH\_A of the public key PUBLICKEY\_A of the issuer of the certificate information INFO, or of the public key PUBLICKEY\_A obtained by an arbitrary hashing algorithm. The value of the subject field is defined as the hash value HASH\_D of the public key PUBLICKEY\_D of the authorizee, or of a public key PUBLICKEY\_D obtained by an arbitrary hashing algorithm. The value of the tag field is data for permitting a DNS query for retrieving the IP address IPADDRESS\_B of the VPN gateway unit (B) 103; the data contains the hash value HASH\_B of the public key PUBLICKEY\_B of the VPN gateway unit (B) 103, or of a public key PUBLICKEY\_B obtained by an arbitrary hashing algorithm. The value of the delegation field is defined as a character string “propagate” defined in non-patent document 4. On the other hand, since the value of the validity field has no direct bearing on the present invention, no value is defined. The certificate information INFO is signed with the private key PRIVATEKEY\_A.

[0029] Referring next to Fig. 2, the general outline of the operation of the Fig. 1 system will be described. During entry (storage) of the access control (ACL) the VPN gateway unit (B) 103 sends its public key PUBLICKEY\_B (or its hash value HASH\_B) to the mediating apparatus (S) 104 (step S1). The mediating apparatus (S) 104 stores the public key PUBLICKEY\_B (or its hash value HASH\_B) and the access control list (ACL).

In the case of connecting a remote VPN from the VPN client unit (A) 101 to the communication unit (C) 111 via the VPN gateway unit (B) 103 in

an IPsec tunnel mode, the VPN client unit (A) 101 sends the public key PUBLICKEY\_A and the public key PUBLICKEY\_B (or their hash values HASH\_A and HASH\_B) to the mediating apparatus (S) 104 to request it to retrieve the IP addresses of the VPN gateway unit (B) 103 and the communication unit (C) (step S2).

[0030] The mediating apparatus (S) 104 executes access authorization control of the VPN client unit (A) 101 by the SPKI scheme, and in the case of authorizing access, it searches the domain name server (DNS) 105 to obtain the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103

(step S3). Then the mediating (S) 104 refers to the access control (ACL) to obtain the private IP address IPADDRESS\_C assigned to the communication unit (C) 111 connected to LAN 110 that is placed under the management of the VPN gateway unit (B) 103. Then the mediating apparatus (S) 104

generates a common key KEY\_AB that is used for mutual authentication of

the VPN client unit (A) 101 and the VPN gateway unit (B) 103. Then the mediating apparatus (S) 104 uses the public key PUBLICKEY\_A of the VPN client unit (A) 101 to encrypt the communication channel between the mediating apparatus (S) 104 and the VPN client unit (A) 101, and sends the IP addresses IPADDRESS\_B and IPADDRESS\_C and the common key

KEY\_AB to the VPN client unit (A) 101 over the encrypted communication channel (step S4). Then the mediating apparatus (S) 104 uses the public key PUBLICKEY\_B of the VPN gateway unit (B) 103 to encrypt the

communication channel between the mediating apparatus (S) 104 and the VPN gateway unit (B) 103, and sends the IP address IPADDRESS\_A and the

common key KEY\_AB to the VPN gateway unit (B) 103 over the encrypted communication channel (step S5). Thus the VPN client unit (A) 101 and the VPN gateway unit (B) 103 are enabled to carry out communications between

them with security by use of the common key KEY\_AB. This embodiment uses the IPsec tunnel mode as a tunneling protocol between the VPN client units (A) 101 and the VPN gateway unit (B) 103, and the common key as information that is sent from the mediating apparatus (S) 104 to them for their mutual authentication. Other protocols such as L2TP and PPTP may be used as the tunnel protocol, and the mutual authentication information may also be ID, a password, a common secret, an SPKI authorization certificate, or similar information of other means.

[0031] In the case of delegating to the VPN client unit (D) 102 the authority for retrieving the IP address of the VPN gateway unit (B) 103, the VPN client unit (A) 101 sends a certificate CERT to the VPN client unit (D) 102 by the SPKI scheme (step S6). The VPN client unit (C) 102 sends its public key PUBLICKEY\_D and the certificate CERT, and the public key PUBLICKEY\_B (or its hash value HASH\_B) to the mediating apparatus (S) 104 to make a request for retrieval of the IP addresses of the VPN gateway unit (B) 103 and the communication unit (C) (step S7).

The mediating apparatus (S) 104 exercises the access authorization control for the VPN client unit (D) 102 by the SPKI scheme, and in the case of authorizing access, the mediating apparatus searches the domain name server (DCS) 105 to obtain the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103 (step S8). Then the mediating apparatus (S) 104 refers to the access control list (ACL) to obtain the private IP address IPADDRESS\_C of the communication unit (C) 111 connected to LAN 110 that is placed under the management of the VPN gateway unit (B) 103.

Then the mediating apparatus (S) 104 generates a common key KEY\_DB that is used for mutual authentication between the VPN gateway unit (B) 103 and the VPN client unit (D) 102. Then the mediating apparatus (S) 104 uses the

public key PUBLICKEY\_D of the VPN client unit (C) 102 to encrypt the communication channel between the mediating apparatus (S) 104 and the VPN client unit (D) 102, and sends the IP addresses IPADDRESS\_B and IPADDRESS\_C and the common key KEY\_DB to the VPN client unit (D)

5 102 over the encrypted communication channel (step S9). Then the mediating apparatus (S) 104 uses the public key PUBLICKEY\_B of the VPN gateway unit (B) 103 to encrypt the communication channel between the mediating apparatus (S) 104 and the VPN gateway unit (B) 103, and sends the IP address IPADDRESS\_D and the common key KEY\_DB to the VPN  
10 gateway unit (B) 103 (step S10). Thus the VPN client unit (D) 102 and the VPN gateway unit (B) are enabled to carry out secure communications between them by use of the common key KEY\_DB.

[0032] Up to this point the description has been given of the configuration of each unit and apparatus of the Fig. 1 system and the general outline of its

15 entire operation, but no detailed description will be given of the IP address management and name resolution methods in the domain name server (DNS) 105, the method of encryption of the communication channel by the IPsec transport mode or tunnel mode, the method of generating the common keys KEY\_AB and KEY\_DB, and the signature verification method using public  
20 keys because these methods are well-known to those skilled in the art.

Besides, in the case of using the name certificate as well as the authorization certificate, too, the access authorization control by the SPKI scheme can be implemented by the same method as that used in this embodiment; therefore, no detailed description will be made.

25 [0033] A detailed description will be given below of the access control list (ACL) storage procedure, the acquisition of the IP address, the generation of the common key, and the procedure for sending the IP address and the

common key. Referring first to Fig. 5, the procedure for storing the access control list (ACL) in the mediating apparatus (S) will be described in detail. Incidentally, it is assumed in this embodiment that the access control list is retained and managed in the VPN gateway unit (B) 103 itself.

5           The VPN gateway unit (B) 103 and the mediating apparatus (S) 104 are connected in the IPsec transport mode (step 1001). By this, the communication channel between the VPN gateway unit (B) 103 and the mediating apparatus (S) 104 is encrypted. The VPN gateway unit (B) 103 sends over the encrypted communication channel the public key  
 10   PUBLICKEY\_B and the SPKI-formatted access control list (ACL) (Fig. 8) (step 1002). The mediating apparatus (S) 104 receives the public key PUBLIVKEY\_B and the access control list (ACL) sent from the VPN gateway unit (B) 103, and stores the received public key PUBLICKEY\_B and access control list (ACL) in association with each other (step 1003). The  
 15   VPN gateway unit (B) 103 and the mediating apparatus (S) 104 are disconnected from each other (step 1004).  
 [0034] Incidentally, in the case where a VPN gateway management unit (M) 112 is provided which has a right of managing the access control list (ACL) for the above-mentioned VPN gateway unit (B) 103, the processing by the  
 20   gateway unit (B) 103 in the access control list (ACL) entering procedure is performed entirely by the VPN gateway management unit (M) 112.

Referring next to Figs. 6 and 7, a description will be given of the procedure by which the mediating apparatus (S) 104: generates the common key KEY\_AB between the VPN client unit (A) 101 and the VPN gateway unit  
 25   (B) 103; sends to the VPN client unit (A) 101 the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, the private address IPADDRESS\_C assigned to the communication unit (C), and the common

key KEY\_AB; and sends to the VPN gateway unit (B) 103 the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and the common key KEY\_AB.

[0035] In Fig. 6, the VPN client unit (A) 101 and the mediating apparatus (S) 104 are connected to each other in the IPsec transport mode (step 1101). In other words, the communication channel between the VPN client unit (A) 101 and the mediating apparatus (S) 104 is encrypted. The VPN client unit (A) 101 sends over the encrypted communication channel a DNS query QUERY containing the public key PUBLICKEY\_B of the VPN gateway unit (B) 103 and the public key PUBLICKEY\_A of the VPN client unit (A) 101 to the mediating apparatus (S) 103 (step 1102).

The mediating apparatus (S) 104 acquires the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, the private address IPADDRESS\_C assigned to the communication unit (C) 111 connected to LAN 110 placed under the management of the VPN gateway unit (B) 103, and the attribute information ATTRIBUTE\_A of the VPN client unit (A) 101, and generates the common key KEY\_AB that is used authentication by IKE or the like between the VPN client unit (A) 101 and the VPN gateway unit (B) 103 (step 1103). Fig. 7 is a detailed flowchart of step 1103.

[0036] In Fig. 7, the mediating apparatus (S) 104 receives and inputs thereto the DNS query QUERY and public key PUBLICKEY\_A sent from the VPN client unit (A) 101 (step 1201). Then the mediating apparatus refers to the input DNS query QUERY to fetch therefrom the public key PUBLICKEY\_B (step 1202). Then the mediating apparatus uses the fetched public key PUBLICKEY\_B to obtain the access control list (ACL) associated with the

public key (step 1203). The access control list (ACL) has the format shown in Fig. 8. Next, the mediating apparatus generates data TAG of the format shown in Fig. 9 by use of the DNS query QUERY input thereto in step 1201 (step 1204).

- 5 [0037] The mediating apparatus (S) 104 uses the public key PUBLICKEY\_A input thereto in step 1201, the data TAG generated in step 1204, and the access control list (ACL) acquired in step 1203 to conduct an operation, for instance, based on the reduction operation rules defined in non-patent documents 4 and 5 (step 1205), thereby deciding whether the mediating  
10 apparatus succeeds in the operation or not (step 1206). When the mediating apparatus fails in the operation, it discontinues processing at this point in time.

Only when it is decided in step 1206 that the mediating apparatus (S) 104 has succeeded in the operation, it outputs operation-result data DATA of  
15 the format shown in Fig. 10. The operation-result data DATA shown in Fig. 10 is data of the 5-tuple format defined in non-patent documents 4 and 5. Only when the ACL entry in which the value of the subject field of the operation-result data DATA completely matches the SHA-1 algorithm-based hash value HASH\_A of the public key PUBLICKEY\_A received in step 1201  
20 is contained in the access control list (ACL) obtained in step 1203, the tag field of data DATA in Fig. 10 contains a character string that completely matches the data TAG in Fig. 9.

[0038] The mediating apparatus (S) 104 refers to the tag field of the output data DATA of Fig. 10, and generates a DNS query QUERY' (step 1207).

- 25 Then the mediating apparatus presents the DNS query QUERY' to the domain name server (DNS)105, and retrieves therefrom the IP address IPADDRESS\_B (step 1208). Then the mediating apparatus searches the

access control list ACL on the basis of the hash value HASH\_A of the public key PUBLICKEY\_A to obtain an (ACL) entry ENTRY containing, in its subject field, a character string which completely matches the hash value HASH\_A (step 1209). Then the mediating apparatus refers to the tag field of the ACL entry ENTRY obtained in step 1209, and obtains the private IP address IPADDRESS\_C and the attribute information ATTRIBUTE\_A (step 1210). Then the mediating apparatus obtains the IP address IPADDRESS\_A of the VPN client unit (A) 101 (step 1211). This is followed by the generation of the common key KEY\_AB (step 1212).

10 [0039] Turning back to Fig. 6, the mediating apparatus (S) 104 sends the IP address IPADDRESS\_B and the private IP address IPADDRESS\_C obtained as mentioned above and the generated common key KEY\_AB to the VPN client unit (A) 101 over the communication channel encrypted in step 1101 (step 1104). Then the client unit (A) 101 and the mediating apparatus (S) 104 are disconnected from each other (step 1105).

Next, the VPN gateway unit (B) 103 and the mediating apparatus (S) 104 are connected to each other in the IPsec transport mode (step 1106). That is, the communication channel between the VPN gateway unit (B) 103 and the mediating apparatus (S) 104 is encrypted. Then the mediating apparatus (S) 104 sends the previously acquired IP address IPADDRESS\_A and attribute information ATTRIBUTE\_A and the previously generated common key KEY\_AB to the VPN gateway unit (B) 103 over the communication channel encrypted in step 1106 (step 1107). Then the VPN gateway unit (B) 103 and the mediating apparatus (S) 104 are disconnected from each other (step 1108).

[0040] Thereafter, the remote-access VPN from the client unit (A) 101 to the communication unit (C) 111 is implemented in the IPsec tunnel mode via the

VPC gateway unit (B) 103 as depicted in Fig. 2; but no detailed description will be given of this operation.

Next, a description will be given below the procedure by which the VPN client unit (A) 101 issues the certificate CERT and passes its issued certificate CERT to the VPN client unit (D) 102. Incidentally, no flowchart will be shown.

(1) The VPN client unit (A) 101 generates the certificate information INFO on the certificate CERT in conformity to the grammar defined in the SPKI scheme. Fig. 11 shows an example of the certificate CERT in this embodiment. In Fig. 11, the value of the issuer field in the certificate information INFO is defined as the hash value HASH\_A of the public key PUBLICKEY\_A that is obtained by an arbitrary hashing algorithm. And the value of the subject field is defined as an SHA-1 algorithm-based hash value HASH\_D of the public key PUBLICKEY\_D. Further, the value of the tag field is defined as the IP address IPADDRESS\_B assigned to the VPN gateway unit (B). The value of the delegation field is defined as the character string "propagate" defined in non-patent document 5. On the other hand, the value of the validity field can be defined as an arbitrary value because it is not directly related to the present invention.

(2) The VPN client unit (A) 101 issues the certificate CERT by signing the data generated in (1) through use of the private key PRIVATEKEY\_A.

(3) The VPN client unit (A) 101 sends the certificate CERT issued in (2) to the VPN client unit (D) 102 by arbitrary means.

(4) The VPN client unit (D) 102 receives and stores the certificate CERT sent in its entirety from the VPN client unit (A) 101 by arbitrary means.

[0041] The procedure, by which the mediating apparatus (S) 104: generates the common key KEY\_DB that is used for authentication by IKE or the like

between the VPN client unit (D) 102 and the VPN gateway unit (B) 103; then sends the IP address IPADDRESS\_B, the private IP address IPADDRESS\_C and the common key KEY\_DB to the VPN client unit (D) 102; and sends the IP address IPADDRESS\_D assigned to the VPN client unit (D) 102, the

5 attribute information ATTRIBUTE\_A of the VPN client unit(A) 101, and the common key KEY\_DB to the VPN gateway unit (B) 103, can be performed in the same manner as that of the procedure described previously with reference to Figs. 6 and 7 by which the mediating apparatus (S) 104: generates the common key KEY\_AB between the VPN client unit (A) 101 and the VPN  
10 gateway unit (B) 103; sends the IP address IPADDRESS\_B, the private IP address IPADDRESS\_C and the common key KEY\_AB to the VPN client unit (A) 101; and sends the IP address IPADDRESS\_A, the attribute information ATTRIBUTE\_A and the common key KEY\_AB to the VPN gateway unit (B) 103.

15 [0042] Thus, the remote-access VPN can also be implemented from the client unit (D) 102 to the communication unit (C) 111 via the VPN gateway unit (B) 103 in the IPsec tunnel mode as depicted in Fig. 2.

As described above, in this embodiment, the mediating apparatus (S) 104 stores the access control list (ACL) sent from the VPN gateway unit (B)  
20 103, thereby storing the private IP address IPADDRESS\_C assigned to the communication unit (C) 111. This enables the mediating apparatus (S) 104 to learn the private IP address IPADDRESS\_C assigned to the communication unit (C) 111 connected to the local area network (LAN) 110 that the VPN gateway unit (B) 103 knows. Accordingly, the VPN client unit (A) 101 can  
25 learn the private IP address IPADDRESS\_C necessary for the remote-access VPN to the communication unit (C) 111 via the VPN gateway unit (B) 103 in the IPsec tunnel mode, by putting a query to the mediating apparatus (S) 104

about it prior to implementation of the remote-access VPN.

[0043] And, in this embodiment the mediating apparatus (S) 104 generates the common key KEY\_AB, and sends the common key KEY\_AB to both of the VPN client unit (A) 101 and the VPN gateway unit (B) 103. As the result of this, the VPN client unit (A) 101 and the VPN gateway unit (B) 103 can receive the common key KEY\_AB. Accordingly, the VPN client unit (A) 101 and the VPN gateway unit (B) 103 can share online the common key KEY\_AB that is used for authentication in the IKE phase 1.

And, in this embodiment, the mediating apparatus (S) 104 authenticates the VPN gateway unit (B) 103, and only when the authentication is successful, the mediating apparatus (S) 104 stores the private IP address IPADDRESS\_C of the communication unit (C) 111 sent from the VPN gateway unit (B) 103. This enables the mediating apparatus (S) 104 to store the private IP address IPADDRESS\_C sent from a non-masqueraded VPN gateway unit (B) 103. Accordingly, the VPN client unit (A) 101 can learn the private IP address IPADDRESS\_C sent from a valid VPN gateway unit (B) 103.

[0044] And, in this embodiment, the mediating apparatus (S) 104 encrypts the communication channel between it and the VPN gateway (B) 103 in the operation of the mediating apparatus (S) 104 that authenticates the VPN gateway unit (B) 103 and stores the private IP address IPADDRESS\_C of the communication unit (C) 111 sent from the VPN gateway unit (B) 103 only when the authentication is successful. This ensures that the mediating apparatus (S) 104 receives the private IP address IPADDRESS\_C of the communication unit (C) 111 sent from the VPN gateway unit (B) 103 without tampering and eavesdropping of the IP address. Accordingly, the VPN client unit (A) 101 can learn a valid private IP address IPADDRESS\_C of the

communication unit (C) 111 sent from a valid VPN gateway unit (B) 103. Besides, the VPN gateway unit (B) 103 can send the valid private IP address IPADDRESS\_C of the communication unit (C) 111 to the mediating apparatus (S) 104 without allowing it to become known to an indefinite number of general public.

[0045] And, in this embodiment, the mediating apparatus (S) 104:

authenticates the VPN client unit (A) 101; and, only when the authentication is successful, obtains the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103 from the domain name server (DNS) 105 by putting

thereto a query about it, then generates the common key KEY\_AB, and sends all of the thus obtained IP address IPADDRESS\_B, the IP address

IPADDRESS\_C assigned to the communication unit (C) 111, and the generated common key KEY\_AB to the VPN client unit (A) 101. As a

result, unless the VPN client unit (A) 101 is masqueraded, the mediating

apparatus (S) 104 is allowed to send all of the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, the private IP address

IPADDRESS\_C assigned to the communication unit (C) 111, and the

common key KEY\_AB to the VPN client unit (A) 101. Accordingly, only the valid VPN client unit (A) 101 is allowed to implement the remote-access

VPN to the communication unit (A) 111 via the VPN gateway unit (B) 103 in the IPsec tunnel mode.

[0046] And, in this embodiment, the mediating apparatus (S) 104: decides

whether or not the VPN client unit (A) 101 has the right to retrieve the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103; and only

when the VPN gateway unit has the right, obtains the IP address

IPADDRESS\_B assigned to the VPN gateway unit (B) 103 from the domain name server (DNS) 105 by putting thereto a query, then generates the

common key KEY\_AB, and sends all of the thus obtained IP address IPADDRESS\_B, the IP address IPADDRESS\_C assigned to the communication unit (C) 111, and the generated common key KEY\_AB to the VPN client unit (A) 101. This enables the mediating apparatus (S) 104 to send all of the IP address IPADDRESS\_B assigned to the gateway unit (B) 103, the private IP address IPADDRESS\_C assigned to the communication unit (C) 111, and the common key KEY\_AB only to the VPN gateway unit (B) 103 and the VPN client unit (A) 101 having the authority of access to the communication unit (C) 111. Accordingly, it is possible to protect the VPN gateway unit (B) 103 and the communication unit (C) 111 from the remote-access VPN in the IPsec tunnel mode from an indefinite number of general public.

[0047] And, in this embodiment, the mediating apparatus (S) 104 encrypts the communication channel between the mediating apparatus (S) 104 and the VPN client unit (A) 101. Hence, the mediating apparatus (S) 104 can send the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, the private IP address IPADDRESS\_C assigned to the communication unit (C) 111 and the common key KEY\_AB to the VPN client unit (A) 101 without their tampering and eavesdropping. Accordingly, the VPN client unit (A) 101 can implement the remote-access VPN to the valid communication unit (C) 111 via the valid VPN gateway unit (B) 103 in the IPsec tunnel mode.

[0048] And, in this embodiment, the mediating apparatus (S) 104 authenticates the VPN gateway unit (B) 103, and only when the authentication is successful, it sends the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and the common key KEY\_AB to the VPN gateway unit (B) 103. As a result, unless the VPN gateway unit (B) 103 is masqueraded, the mediating

apparatus (S) 104 can send the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and the common key KEY\_AB to the VPN gateway unit (B) 103. This produces an effect that the VPN client unit (A) 101 is allowed to implement the remote-access VPN to the communication unit (C) 111 via the valid VPN gateway unit (B) 103 in the IPsec tunnel mode.

[0049] And, in this embodiment, the mediating apparatus (S) 104 encrypts the communication channel between it and the VPN gateway (B) 103 in the operation of the mediating apparatus (S) 104 that authenticates the VPN gateway unit (B) 103 and sends the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and the common key KEY\_AB to the VPN gateway unit (B) 103 only when the authentication is successful. This ensures that the mediating apparatus (S) 104 sends all of the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and the common key KEY\_AB to the VPN gateway unit (B) 103 without their tampering and eavesdropping. Accordingly, the VPN gateway unit (B) 103 and the communication unit (C) 111 can implement the remote-access VPN to the valid VPN client unit (A) 101 in the IPsec tunnel mode.

[0050] And, in this embodiment, the mediating apparatus (S) 104 authenticates the VPN client unit (A) 101 and the VPN gateway unit (B) 103 by the SPKI scheme. This permits identity certification by signature verification, eliminating the need for sending a public key certificate from either of the VPN client unit (A) 101 and the VPN gateway unit (B) 103 to the mediating apparatus (S) 104. Accordingly, both of the VPN client unit (A) 101 and the VPN gateway unit (B) 103 can conceal their personal information from the mediating apparatus S.

And, in this embodiment, the VPN client unit (A) 101 issues the certificate CERT by the SPKI scheme and sends it to the VPN client unit (D) 102. Since this enables the VPN client unit (A) 101 to delegate to the VPN client unit (D) 102 a right to retrieve the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, the VPN client unit (D) 102 can retrieve the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103.

Further, the VPN client unit (D) 102 can obtain the private IP address IPADDRESS\_C assigned to the communication unit (C) 111. Accordingly, the VPN client unit (D) 102 can also implement the remote-access VPN to the communication unit (C) 111 via the VPN gateway unit (B) 103 in the IPsec tunnel mode. Besides, the VPN gateway unit (B) 103 is capable of permitting implementation of the remote-access VPN from the VPN client unit (D) 102 without the need for adding information about the VPN client unit (D) 102 to the access control list (ACL). Hence, the VPN gateway unit (B) 103 reduces the cost for management such as editing of the access control list (ACL).

[0051] Incidentally, the placement of the hash value HASH\_B of the public key PUBLICKEY\_B and IPADDRESS\_B under associated management of the domain name server (DNS) 105 shown in Figs. 1 and 2 can also be achieved by a procedure by which the VPN gateway unit (B) 103 generates the hash value HASH\_B of its public key PUBLICKEY\_B, then enters the hash value HASH\_B and its IP address IPADDRESS\_B into the domain name server (DNS), and by changing DNS query in the procedure (step 1102) in Fig. 6 to a DNS query containing the hash value HASH\_B of the public key PUBLICKEY\_B by an arbitrary hashing algorithm.

And, in the access control list (ACL) in Fig. 8, the data TAG in Fig. 9, the operation result data DATA in Fig. 10 and the certificate CERT in Fig. 11,

the hash value HASH\_A may be calculated by use of an arbitrary hashing algorithm other than the SHA-1 algorithm. The value of the issuer field may be defined as the public key PUBLICKEY\_A in place of the hash value HASH\_A. Similarly, the value of the subject field may be defined as the public key PUBLICKEY\_D in place of the hash value HASH\_D. Even if these modifications are made, the same results as described above can be obtained with respect to the access control by conducting the operations in accordance with the reduction operation rules defined in the SPKI-related non-patent documents 4 and 5. No detailed description will be given of the format of the certificate CERT in the case of using a hashing algorithm other than the SHA-1 algorithm and the formats of the access control list ACL, the data DATA and the certificate CERT in the case of designating the public key to the issuer field and the subject field, because they are described in detail in the SPKI-related non-patent documents 4 and 5. With the modification, the procedure shown in Fig. 7 (step 1209) can obviously be performed by a procedure of presenting the public key PUBLICKEY\_A to the access control list ACL to retrieve therefrom the ACL entry.

[0052] Further, the VPN client unit (A) 101 shown in Fig. 2 is assigned only the global IP address IPADDRESS\_A, but an arbitrary private IP address in the local area network LAN may be dynamically assigned to the VPN client unit (A) 101 under instructions from the VPN gateway unit (B) 103 by using the methods set forth in patent document 4 and non-patent document 4 at the time of setting up the IPsec tunnel mode between the VPN client unit (A) 101 and the VPN gateway unit (B) 103. Moreover, an arbitrary IP private address in the local area network LAN may be assigned dynamically to the VPN client unit (A) 101 via the communication channel set up in the IPsec transport mode between the mediating apparatus (S) 104 and the VPN client

unit (A) 101 under instructions from the mediating apparatus (S) 104 by use of such a method as set forth in patent document 3.

## EMBODIMENT 2

This embodiment further devises the certificate CERT, and provides the certificate CERT in the form of a 0.509-type public key certificate. The basic system configuration of this embodiment is the same as that of Embodiment 1, but an authentication station is required. Fig. 12 illustrates the general system configuration of this embodiment. In Fig. 12 the VPN client unit (A) 101, the VPN gateway unit (B) 103, an authentication station (CA) 106, the domain name server (DNS) 105, and the mediating apparatus (S) 104 are each connected to the network (WAN) 100 under IP (Internet Protocol) control.

[0053] Fig. 13 is a diagram for explaining the operation of the entire system in Fig. 12. The thick lines indicate the remote-access VPN in the IPsec tunnel mode, and the broken lines indicate presentation of the public key certificate CERT to the authentication station (CA) in the authentication in the IKE phase 1. In this embodiment, too, the host name of the VPN client unit (A) 101 is represented by the public key PUBLICKEY\_A (or its hash value HASH\_A), its IP address by IPADDRESS\_A, the host name of the VPN gateway unit (B) 103 by the public key PUBLICKEY\_B (or its hash value HASH\_B), its IP address by IPADDRESS\_B, and the private IP address of the communication unit (C) 111 by IPADDRESS\_C.

[0054] The IP address IPADDRESS\_A assigned to the VPN client unit (A) 101 and the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103 are both unique in the IP network (WAN) 100, and they are assigned by arbitrary means. The public key PUBLICKEY\_B (or its hash value HASH\_B) and the IP address IPADDRESS\_B of the VPN gateway unit (B)

103 are uniquely associated with each other and placed under the management of the domain name server (DNS) 105. The private IP address IPADDRESS\_C assigned to the communication unit 111 is unique only in the local area network (LAN) 110, and it is dynamically assigned by arbitrary means such as DHCP (Dynamic Host Configuration Protocol) or IPCP (PPP IP control protocol).

[0055] The VPN client unit (A) 101, the VPN gateway unit (B) 103, and the moderating apparatus (S) 104 each have means for encrypting the communication channel in the IPsec transport mode or IPsec tunnel mode.

10 The private key of the public key PUBLICKEY\_A is PRIVATEKEY\_A, which is retained in the VPN client unit (A) 101. CERT\_A is an X.509-format public key certificate containing the public key PUBLICKEY\_A that pairs with the private key PRIVATEKEY\_A, and it is signed with a private key PRIVATEKEY\_R of the authentication station (CA)

15 and retained in the VPN client unit (A) 101. A private key PRIVATEKEY\_B of the public key PUBLICKEY\_B is retained in the VPN gateway unit (B) 103. CERTB is an X.509-format public key certificate containing the public key PUBLICKEY\_B that pairs with the private key PRIVATEKEY\_B, and it is also signed with the private key PRIVATEKEY\_R

20 of the authentication station (CA) 106 and retained in the VPN gateway unit (B) 103. The authentication station (CA) 106 authenticates the public key certificate CERT\_A of the VPN client unit (A) 101 and the public key certificate CERT\_B of the VPN gateway unit (B) 103 by the PKI (Public Key Infrastructure) scheme. The access control list (ACL) is data that the private

25 IP address IPADDRESS\_C and the attribute information ATTRIBUTE\_A of the VPN client unit (A) 101 are associated with a combination of the public key PUBLICKEY\_A and the public key PUBLICKEY\_B, and the list has the

same structure as that shown in Fig. 8 and is retained in the VPN gateway unit (B) 103. A private key PRIVATEKEY\_S is retained in the mediating apparatus (S) 104. CERT\_S is an X.509-format public key certificate containing a public key PUBLICKEY\_S that pairs with the private key PRIVATEKEY\_S, and it is signed with the private key PRIVATEKEY\_R of the authentication station (CA) 106 and retained in the mediating apparatus (S) 104.

[0056] The mediating apparatus is substantially the same in configuration as the mediating apparatus (S) 104 in Embodiment 1, but differs from the latter in that the authentication/access authorization control means 1042 authenticates the client unit (A) 101 and the gateway unit (B) by use of the public key certificates CERT\_A and CERT\_B of the client unit (A) and the gateway unit (B) signed by the authentication station (CA) 106. Therefore, no description will be given of the configuration of the mediating apparatus (S) 104 and, for the mediating apparatus (S) 104, reference will hereinafter be made to Fig. 3.

The IP address acquiring means 1043 retrieves the IP address IPADDRESS\_B from the public key PUBLICKEY\_B by the name resolution scheme called DNS scheme that is common in the Internet. The ACL storage means 1041 manages the access control list (ACL) in association with the public key PUBLICKEY\_B. The authentication/access authorization control means 1042 presents the public key PUBLICKEY\_A contained in the public key certificate CERT\_A to the access control list ACL to search it, and outputs, as the search result, the private IP address IPADDRESS\_C and the attribute information ATTRIBUTE\_A uniquely associated with the combination of the public key PUBLICKEY\_A and the public key PUBLICKEY\_B. The key generating means 1044 generates the common

key KEY\_AB that is used for authentication in the IKE phase 1 between the VPN client unit (A) 101 and the VPN gateway unit (B) 103.

[0057] Next, a description will be given, with reference to Fig. 13, of the general outline of the operation of the Fig. 12 embodiment.

5           At the time of entering (storage) of the access control list (ACL), the VPN gateway unit (B) 103 sends the public key PUBLICKEY\_B (or its hash value HASH\_B) and the access control list (ACL) to the mediating apparatus (S) 104 (step S21). The mediating apparatus (S) 104 stores the access control list (ACL) as the tables of Figs. 4A and 4B in association with the  
10   public key PUBLICKEY\_B (or its hash value HASH\_B). In the case of implementing the remote-access VPN from the VPN client unit (A) 101 to the communication unit (C) 111 via the VPN gateway unit (B) 103 in the IPsec tunnel mode, the VPN client unit (A) 101 sends the public key  
PUBLICKEY\_A and the public key PUBLICKEY\_B (or its hash value  
15   HASH\_B) to the mediating apparatus (S) 104 to make a request for retrieval of the IP addresses of the VPN gateway unit (B) 103 and the communication unit (C) 111(step S22).

[0058] In the case where the authentication/access authorization control means 1042 executes the access authorization control for the VPN client unit  
20   (A) 101 by the PKI scheme for granting it access authorization, the mediating apparatus (S) 104 searches the domain name server (DNS) 105 and retrieves therefrom the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103 (step S23). The mediating apparatus (S) 104 refers to the access control list (ACL) to obtain therefrom the private IP address IPADDRESS\_C  
25   and attribute information ATTRIBUTE\_A of the communication unit (C) 111 connected to the LAN 110 placed under the management of the VPN gateway unit (B) 103. Furthermore, the mediating apparatus (S) 104 generates the

common key KEA\_B that is used for authentication between the VPN client unit (A) 101 and the VPN gateway unit (B) 103. And, the mediating apparatus (S) 104 encrypts the communication channel between the mediating apparatus (S) 104 and the VPN client unit (A) 101, through which it sends the  
5 IP addresses IPADDRESS\_B, IPADDRESS\_C and the common key KEY\_AB to the VPN client unit (A) 101 (step S24). Moreover, the mediating apparatus (S) 104 encrypts the communication channel between the mediating apparatus (S) 104 and the VPN gateway unit (B) 103, through which it sends the IP address IPADDRESS\_A, the attribute information  
10 ATTRIBUTE\_A and the common key KEY\_AB to the VPN gateway unit (B) 103 (step S25).

[0059] Up to this point the configuration of each unit and apparatus of the Fig. 12 system and the general outline of its operation have been described, but no detailed description will be given of the IP address management and name  
15 resolution methods in the domain name server (DNS) 105, the communication channel encryption method of by the IPsec transport mode or tunnel mode, the method of generating the common keys KEY\_AB, and the method for authentication of the X.509-format public key certificates CERT\_A and CERT\_B, because these methods are well-known to those skilled in the art.

20 A detailed description will be given below of the access control list (ACL) storage procedure and the procedures for acquiring the IP addresses, generation of the common keys and sending of these IP addresses and common keys in Embodiment 2.

[0060] Referring first to Figs. 14 and 15, a description will be given of the  
25 procedure by which the access control list (ACL) retained in the VPN gateway unit (B) 103 is stored in the mediating apparatus (S) 104.

In Fig. 14, the VPN gateway unit (B) 103 and the mediating apparatus

(S) 104 are connected with each other in the IPsec transport mode (step 1301). The authentication in the IKE phase 1 is performed by the PKI scheme; the VPN gateway unit (B) 103 sends the public key certificate CERT\_B, and the mediating apparatus (S) 104 sends the public key certificate CERT\_S. The VPN gateway unit (B) 103 puts a query to the authentication station (CA) 106 about the received public key certificate CERT\_S to authenticate the validity of the public key certificate CERT\_S by the PKI scheme. Similarly, the mediating apparatus (S) 104 puts a query to the authentication station (CA) about the received public key certificate CERT\_B to authenticate the validity of the public key certificate CERT\_B by the PKI scheme.

[0061] The VPN gateway unit (B) 103 sends the access control list (ACL) in its entirety over the communication channel encrypted in step 1301 (step 1302). The mediating apparatus (S) 104 enters therein the access control list (ACL) sent from the VPN gateway unit (B) 103 (step 1303). Thereafter, the VPN gateway unit (B) 103 and the mediating apparatus (S) 104 are disconnected from each other (step 1304).

Fig. 15 is a flowchart showing in detail the procedure by which the mediating apparatus (S) 104 enters therein the access control list (ACL). In the first place, the mediating apparatus (S) 104 receives the access control list (ACL) in its entirety sent from the VPN gateway unit (B) 103 (step 1401). Then the mediating apparatus refers to the public key certificate CERT\_B used in the IKE authentication and obtains the public key PUBLICKEY\_B (step 1402). Then the mediating apparatus stores the thus obtained public key PUBLICKEY\_B and the access control list ACL received in step 1402 in association with each other (step 1403).

[0062] Referring next to Figs. 16 and 17, a description will be given of the procedure by which the mediating apparatus (S) 104: generates the common

key KEY\_AB between the VPN client unit (A) 101 and the VPN gateway unit (B) 103; sends the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, the private IP address IADDRESS\_C and the common key KEY\_AB to the VPN client unit (A) 101; and sends the IP address

- 5 IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A and the common key KEY\_AB to the VPN gateway unit (B) 103.

[0063] In Fig. 16, the VPN client unit (A) 101 and the mediating apparatus (S) 104 are connected to each other in the IPsec transport mode (step 1501).

- 10 The authentication in the IKE phase 1 is performed by the PKI scheme; the VPN client unit (A) 101 sends the public key certificate CERT\_A; and the mediating apparatus (S) 104 sends the public key certificate CERT\_S. The VPN gateway unit (A) 101 put a query to the authentication station (CA) 106 about the received public key certificate CERT\_S to authenticate the validity
- 15 of the public key certificate CERT\_S by the PKI scheme. Similarly, the mediating apparatus (S) 104 puts a query to the authentication station (CA) about the received public key certificate CERT\_A to authenticate the validity of the public key certificate CERT\_A by the PKI scheme.

[0064] The VPN client unit (A) 101 sends the whole of the DNS query

- 20 QUERY containing the public key PUBLICKEY\_B of the VPN gateway unit (B) 103 over the communication channel encrypted in step 1501 (step 1502). The mediating apparatus (S) 104 acquires the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103 and the private IP address
- 25 IPADDRESS\_C assigned to the communication unit (C) 111 connected to LAN 110 placed under the management of the VPN gateway unit (B) 103, and generates the common key KEY\_AB that is used for authentication by

IKE or the like between the VPN client unit (A) 101 and the VPN gateway unit (B) 103 (step 1503). Fig. 17 is a flowchart showing step 1503 in detail.

[0065] In Fig. 17, the mediating apparatus (S) 104 first receives the DNS query in its entirety sent from the VPN client unit (A) 101 (step 1601). Then

5 the mediating apparatus refers to the DNS query input thereto and acquires therefrom the public key KEY\_B in its entirety (step 1602). Then the mediating apparatus uses the public key PUBLICKEY\_B to acquire the whole of the access control list (ACL) associated therewith (step 1603). Then the

10 mediating apparatus refers to the public key certificate CERT\_A used for the IKE phase 1 authentication in step 1501 and acquires the public key PUBLICKEY\_A in its entirety (step 1604). Then the mediating apparatus uses the public key PUBLICKEY\_A to search the access control list (ACL) and acquires therefrom the private IP address IPADDRESS\_C (step 1605).

And the mediating apparatus decides that it has acquired the private IP address IPADDRESS\_C (step 1606), and in the case where any IP addresses cannot be acquired, the procedure discontinued.

[0066] When having acquired the private IP address IPADDRESS\_C, the mediating apparatus S presents the DNS query QUERY received in step 1601, to the domain name server (DNS) 105 to acquire therefrom the IP address

20 IPADDRESS\_B (step 1607). The mediating apparatus acquires the IP address IPADDRESS\_A of the VPN client unit A (step 1608). This is followed by the generation of the common key KEY\_AB (step 1609).

Turning back to Fig. 16, the mediating apparatus (S) 104 sends all of the IP address IPADDRESS\_B obtained in step 1607, the private IP address IPADDRESS\_C obtained in step 1605 and the common key KEY\_AB generated in step 1609 to the VPN client unit (A) over the communication channel encrypted in step 1501 (step 1504). This is followed by

disconnecting the VPN client unit (A) 101 and the mediating apparatus (S) 104 from each other (step 1505).

[0067] Then the VPN gateway unit (B) 103 and mediating apparatus (S) 104 are connected to each other in the IPsec transport mode (step 1506). The

5 authentication in the IKE phase 1 is performed by the PKI scheme; the VPN gateway unit (B) 103 sends the public key certificate CERT\_B and the mediating apparatus (S) 104 sends the public key certificate CERT\_S. The VPN gateway unit (B) 103 puts a query to the authentication station (CA) 106 about the received public key certificate CERT\_S to authenticate the validity  
10 of the public key certificate CERT\_S by the PKI scheme. Similarly, the mediating apparatus (S) 104 puts a query to the authentication station (CA) 106 about received the public key certificate CERT\_B to authenticate its validity by the PKI scheme.

[0068] The mediating apparatus (S) 104 sends all of the attribute information  
15 ATTRIBUTE\_A obtained in step 1605, the IP address IPADDRESS\_A obtained in step 1608, and the common key KEY\_AB generated in step 1609 to the VPN gateway unit (B) 103 over the communication channel encrypted in step 1506 (step 1507). This is followed by disconnecting the VPN gateway unit (B) 103 and the mediating apparatus (S) 104 from each other  
20 (step 1508).

As described above, in this embodiment, by storing the private IP address IPADDRESS\_C assigned to the communication unit (C), sent thereto from the VPN gateway unit (B) 103, the mediating apparatus (S) 104 can learn the private IP address IPADDRESS\_C assigned to the communication  
25 unit (C) 111 connected to the local area network (LAN) which is known only to the VPN gateway unit (B) 103. Accordingly, the VPN client unit (A) 101 can learn the private IP address IPADDRESS\_C necessary for the

remote-access VPN to the communication unit (C) 111 via the VPN gateway unit (B) 103 in the IPsec tunnel mode, by making putting a query to the mediating apparatus (S) 104 prior to implementation of the remote-access VPN.

- 5 [0069] And, in this embodiment the mediating apparatus (S) 104 generates the common key KEY\_AB, and sends the common key KEY\_AB to both of the VPN client unit (A) 101 and the VPN gateway unit (B) 103, by which the VPN client unit (A) 101 and the VPN gateway unit (B) 103 are allowed to receive the common key KEY\_AB. Accordingly, the VPN client unit (A) 101 and the VPN gateway unit (B) 103 can share online the common key KEY\_AB that is used for authentication in the IKE phase 1.

- And, in this embodiment the mediating apparatus (S) 104 authenticates the VPN gateway unit (B) 103, and only when the authentication is successful, the mediating apparatus (S) 104 stores the private IP address IPADDRESS\_C of the communication unit (C) 111 sent from the VPN gateway unit (B) 103. This enables the mediating apparatus (S) 104 to store the private IP address IPADDRESS\_C alone that is sent from a non-masqueraded VPN gateway unit (B) 103. Accordingly, the VPN client unit (A) 101 can learn the private IP address IPADDRESS\_C sent from the valid VPN gateway unit (B) 103.

- [0070] And, in this embodiment, the mediating apparatus (S) 104 encrypts the communication channel between it and the VPN gateway (B) 103 in the operation of the mediating apparatus (S) 104 that authenticates the VPN gateway unit (B) 103 and stores the private IP address IPADDRESS\_C of the communication unit (C) 111 sent from the VPN gateway unit (B) 103 only when the authentication is successful. This ensures that the mediating apparatus (S) 104 receives the private IP address IPADDRESS\_C of the

communication unit (C) 111 sent from the VPN gateway unit (B) 103 without tampering and eavesdropping of the IP address. Accordingly, the VPN client unit (A) 101 can learn the valid private IP address IPADDRESS\_C of the communication unit (C) 111 sent from the valid VPN gateway unit (B) 103.

- 5 Besides, the VPN gateway unit (B) 103 can send the valid private IP address IPADDRESS\_C of the communication unit (C) 111 to the mediating apparatus (S) 104 without allowing it to become known to an indefinite number of general public.

[0071] And, in this embodiment, the mediating apparatus (S) 104:

- 10 authenticates the VPN client unit (A) 101; and, only when the authentication is successful, obtains the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103 from the domain name server (DNS) 105 by putting thereto a query; then generates the common key KEY\_AB, and sends all of the thus obtained IP address IPADDRESS\_B, the IP address IPADDRESS\_C
- 15 assigned to the communication unit (C) 111 and the generated common key KEY\_AB to the VPN client unit (A) 101. As a result, unless the VPN client unit (A) 101 is masqueraded, the mediating apparatus (S) 104 is allowed to send all of the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, the private IP address IPADDRESS\_C assigned to the
- 20 communication unit (C) 111, and the common key KEY\_AB to the VPN client unit (A) 101. Accordingly, only the valid VPN client unit (A) 101 is allowed to implement the remote-access VPN to the communication unit (A) 111 via the VPN gateway unit (B) 103 in the IPsec tunnel mode.

[0072] And, in this embodiment, the mediating apparatus (S) 104: decides

- 25 whether or not the VPN client unit (A) 101 has the right to retrieve the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103; and only when the VPN gateway unit has the right, obtains the IP address

IPADDRESS\_B assigned to the VPN gateway unit (B) 103 from the domain name server (DNS) 105 by putting thereto a query, then generates the common key KEY\_AB, and sends all of the thus obtained IP address IPADDRESS\_B, the IP address IPADDRESS\_C assigned to the

5 communication unit (C) 111, and the generated common key KEY\_AB to the VPN client unit (A) 101. This enables the mediating apparatus (S) 104 to send all of the IP address IPADDRESS\_B assigned to the gateway unit (B) 103, the private IP address IPADDRESS\_C assigned to the communication unit (C) 111, and the common key KEY\_AB only to the VPN gateway unit  
10 (B) 103 and the VPN client unit (A) 101 having the authority of access to the communication unit (C) 111. Accordingly, it is possible to protect the VPN gateway unit (B) 103 and the communication unit (C) 111 from the remote-access VPN in the IPsec tunnel mode from an indefinite number of general public.

15 [0073] And, in this embodiment, the mediating unit (S) 104 encrypts the communication channel between the mediating apparatus (S) 104 and the VPN client unit (A) 101. Hence, the mediating apparatus (S) 104 can send the IP address IPADDRESS\_B assigned to the VPN gateway unit (B) 103, the private IP address IPADDRESS\_C assigned to the communication unit (C)  
20 111 and the common key KEY\_AB to the VPN client unit (A) without tampering and eavesdropping of them. Accordingly, the VPN client unit (A) 101 can implement the remote-access VPN to the valid communication unit (C) 111 via the valid VPN gateway unit (B) 103 in the IPsec tunnel mode.

[0074] And, in this embodiment, the mediating apparatus (S) 104  
25 authenticates the VPN gateway unit (B) 103, and only when the authentication is successful, it sends the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and

the common key KEY\_AB to the VPN gateway unit (B) 103. As a result, unless the VPN gateway unit (B) 103 is masqueraded, the mediating apparatus (S) 104 can send the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and the common key KEY\_AB to the VPN gateway unit (B) 103. Accordingly, the VPN client unit (A) 101 is allowed to implement the remote-access VPN to the communication unit (C) 111 via the valid VPN gateway unit (B) 103 in the IPsec tunnel mode.

[0075] And, in this embodiment, the mediating apparatus (S) 104 encrypts the communication channel between it and the VPN gateway (B) 103 in the operation of the mediating apparatus (S) 104 that authenticates the VPN gateway unit (B) 103 and sends the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and the common key KEY\_AB to the VPN gateway unit (B) 103 only when the authentication is successful. This ensures that the mediating apparatus (S) 104 sends all of the IP address IPADDRESS\_A assigned to the VPN client unit (A) 101, its attribute information ATTRIBUTE\_A, and the common key KEY\_AB to the VPN gateway unit (B) 103 without their tampering and eavesdropping. Accordingly, the VPN gateway unit (B) 103 and the communication unit (C) 111 can implement the remote-access VPN to the valid VPN client unit (A) 101 in the IPsec tunnel mode.

[0076] And, in this embodiment, the mediating apparatus (S) 104 authenticates the VPN client unit (A) 101 and the VPN gateway unit (B) 103 by the SPKI scheme. This permits authentication of the public key certificate CERT\_A of the VPN client unit (A) 101 and the public key certificate CERT\_B of the VPN gateway unit (B) 103 by sending them to the mediating apparatus (S) 104. Accordingly, personal information on the VPN

client unit (A) 101 can be concealed from the VPN gateway unit (B) 103. Similarly, personal information on the VPN gateway unit (B) 103 can be concealed from the VPN client unit (A) 101.

[0077] Incidentally, in the case where the hash value HASH\_B of the public

5 key PUBLICKEY\_B, an arbitrary hashing algorithm, and its IP address IPADDRESS\_B are managed in association with each other in the domain name server (DNS) 105 in this embodiment, shown in Figs. 12 and 13, the VPN gateway unit (B) 103 needs only to generate the hash value HASH\_B of the public key PUBLICKEY\_B and enter the hash value HASH\_B and the IP  
10 address IPADDRESS\_B into the domain name server (DNS) 105. And, obviously, this can also be achieved by changing the DNS query in step 1502 of the Fig. 16 procedure to a DNA query containing the hash value HASH\_B of the public key PUBLICKEY\_B by an arbitrary hashing algorithm.

[0078] And, instead of associated management of the public key

15 PUBLICKEY\_A and the IP address IPADDRESS\_C in the access control list (ACL), the hash value HASH\_A of the public key PUBLICKEY\_A by an arbitrary hashing algorithm and the IP address IPADDRESS\_C may be placed under associated management of the access control list. Obviously, this modification can be made by changing step 1302 of the Fig. 14 procedure to a  
20 step wherein the VPN gateway unit (B) 103 generates the hash value HASH\_A of the public key PUBLICKEY\_A and then sends the hash value HASH\_A and the IP address IPADDRESS\_C as associated data to the access control list (ACL). Further, the modification can be made by changing step 1605 of the Fig. 17 procedure to a step of generating the hash value HASH\_A  
25 of the public key PUBLICKEY\_A and presenting the hash value HASH\_A to the access control list ACL to search it.

[0079] Further, only the global IP address IPADDRESS\_A is assigned to the

VPN client unit (A) 101, but an arbitrary private IP address in the local area network LAN may also be additionally assigned to the VPN client unit (A) 101 by such a method as set forth in non-patent document 4.

### EMBODIMENT 3

Fig. 18 illustrates a practical functional configuration of the VPN client unit in Embodiments 1 and 2 described above. The VPN client unit 101 is provided with: a DNS query capture/proxy answer function part 1011 that captures a DNS request from this unit and makes a proxy answer thereto; a mediation-service VPN client function part 1012 that performs a VPN client function of the mediation service of the present invention; and a tunneling protocol function part 1013 for implementing VPN access. Furthermore, there are provided: a mediation service management table 1014 for distinguishing between ordinary DNS queries and mediation services, and for their management; a mediation-service authentication information table 1015 for mutual authentication with a mediation server; and a tunneling/protocol configuration management information table 1016 for encrypted communications with the VPN gateway unit.

[0080] The mediation service management table 1014 has stored therein:

a) Postfix for mediation service: domain name that is transferred to mediation service (e.g. \*.vpn),

b) IP address or host name of the mediating apparatus: IP address of the mediating apparatus,

c) Authentication scheme with the mediating apparatus (SPKI scheme, PKI scheme, challenge-response scheme, key-sharing scheme, etc.),

d) Name of certificate for authentication (refer to certificate/secret data corresponding to authentication scheme).

[0081] The mediation-service authentication information table 1015 has

stored therein:

a) Table of hash values corresponding to domain names that are used to search the VPN gateway unit,

b) Various certificates that are used for client authentication by the VPN client unit (SPKI certificate, PKI certificate, password, common key, etc.),

c) Certificates that are used for authentication of the mediating apparatus by the server (SPKI certificate, PKI certificate, password, common key, etc.)

[0082] The tunneling/protocol configuration management table is roughly classified into the following two kinds:

(1) Configuration management information for setting up a tunnel; and

(2) Configuration management information on the set-up tunnel as a virtual network interface (Nw.I/F). Their detailed examples are given below.

(1) Configuration management information for setting up a tunnel

A) IP address of the tunnel starting point (IP address given to the VPN client unit from the network).

[0083] B) IP address of the tunnel terminating point (IP address given to the VPN gateway unit from the network).

C) Protocol for tunneling (IPsec tunnel mode, PPP over IPsec, etc.).

D) Authentication scheme (SPKI scheme, PKI scheme, challenge-response scheme, key-sharing scheme, etc.)

E) Name or the like of the certificate for authentication (refer to the certification/secret data corresponding to the authentication scheme).

(2) Configuration management information on the set-up tunnel as a network interface (Nw.I/F)

a) Kind of virtual Nw.I/F (virtual PPP, virtual Ethernet, etc.),

- b) IP address of virtual Nw.I/F
- c) IP addresses of gateway, DNS server, WIN server, etc.
- d) Information on routing to virtual Nw.I/F.

Those of the above-mentioned pieces of information which are provided from  
 5 the mediating apparatus are:

The information B) in item (1). In addition, the pieces of information C), D) and E) may also be provided.

[0084] Those of pieces of information B), C) and D) in item (2) which are not  
 10 dynamically posted from the VPN gateway unit (which pieces of information may be provided from either one of the mediating apparatus and the VPN gateway unit).

The mediation processing in this embodiment is performed as described below.

In the first place, the application issues, prior to communication, a  
 15 DNS query request for querying about the IP address of the VPN gateway unit that offers a VPN service desired to access (step S1).

This request is captured once by the DNS query capture/proxy answer function part 1011, which refers to the mediation service management table 1014 to decide whether the request concerns the mediation service or not. If  
 20 the request has nothing to do with the mediation service, it is regarded as an ordinary DNS request, then ordinary DNS processing is performed for the DNS server 105 to obtain the IP address from its answer, and ordinary connection processing is carried out using it (step S2).

[0085] If the DNS inquiry request concerns the mediation service, it is  
 25 transferred to the mediation-service VPN client function part 1012 (step S3).

The mediation-service VPN client function part 1012 selects a predetermined mediation server according to the contents of the mediation

service management table 1014 (step S4), and performs mutual authentication using the mediation-service authentication information table 1015 (step S5).

Then the mediation-service VPN client function part sends the mediation request, referred to with respect to the above-described embodiment, to the mediating apparatus 104 (step S6) and obtains its answer (step S7). Based on this information, the mediation-service VPN client function part updates information such as the VPN gateway addresses and common keys in the tunneling/protocol configuration management table 1016 (step S8) and, if a predetermined tunnel is not set up yet, it sends a tunnel set-up request to the tunneling/protocol 1013 (step S9).

[0086] The tunneling/protocol part 1013 refers to the tunneling/protocol configuration management table 1016 to identify the VPN gateway unit 103 that is the opposite side of the tunnel (step S10), and sets up a tunnel for encrypted communications with the VPN gateway unit 103 by use of the common key set by the present mediation function (step S11).

Once the tunnel is normally set up, part of configuration management information, such as the private IP address of the VPN client unit 101, internal DNS and routing-related information, can be dynamically passed from the VPN gateway unit 103 by use of the method set forth in patent document 4, non-patent document 1, non-patent documents 2, or non-patent document 3. In this case, the tunneling/protocol part uses these pieces of information to update the tunneling/protocol configuration management table 1016 (step S12), and sends an answer of tunnel set-up completion to the mediation-service VPN client function part 1012 (step S13).

[0087] When the set-up of the VPN tunnel is normally completed, the mediation-service VPN client function part 1012 sends the private IP address of the communication unit obtained in step S7, as an answer to the DNS query,

to the DNS query capture/proxy answer function part 1011 (step S14). This answer is sent intact to the application that issued the DNS query (step S15). The application conducts VPN communication via the set VPN tunnel (step S16).

#### 5 EMBODIMENT 4

Fig. 19 illustrates an example of the entire system configuration embodying the present invention. In this embodiment, assume that VPN client units 101 and 102 are used for a personnel division and an accounting division, and that they have public key hash values A1 and A2, respectively.

10 Let it be assumed that the VPNs placed under the management of the VPN gateway unit 103 are a personal division VLAN 121 and an accounting division VLAN 122, and that the VPN gateway unit 103 is connected via an ethernet switch 123 to both of VLANs 121 and 122 by IEEE 802.IQ VLAN tag multiplexing. Further, assume that the mediating apparatus 104 has  
 15 pre-uploaded thereto the access control list (ACL) shown in Fig. 20 for the VPN gateway unit 103. In this ACL it is declared that the VPN client unit 101 having a public key of hash value HASH\_A1 has attribute information “(VLAN Personal Division VLAN), whereas the VPN client 102 having a public key of hash value HASH\_A2 has attribute information “(VLAN  
 20 Personnel Division VLAN).

[0088] Fig. 21 illustrates the functional configuration of the VPN gateway unit 103 in this embodiment. The VPN gateway unit 102 is provided with: a mediation-service VPN gateway function part 1031 that performs communications with the mediating apparatus 104 and processing therefor; a  
 25 tunneling/protocol part 1032 that terminates tunnels from multiple VPN client units; a filtering/VLAN multiplex function part 1033 that stores data packets extracted from the tunnels in predetermined VLANs in VPNs and filters out

those of packets input to and output from the tunnels which raise security concerns. Furthermore, there are provided: a mediation service management table 1034 having information necessary for connection with the mediating apparatus 104; a mediation-service authentication information table 1035 for authentication with the mediating apparatus 104; a tunneling/protocol configuration management table 1036 holding configuration management information on tunnels to the VPN client units 101 and 102; and VLAN configuration management table 1037 holding configuration management information on each VLAN placed under the management of the VPN gateway unit 103.

[0089] In the mediation-service management table 1034 there is held the following pieces of information for each mediating apparatus to be used.

a) IP address or host name of the mediating apparatus: IP address of the mediating apparatus.

b) Authentication scheme with the mediating apparatus (SPKI scheme, PKI scheme, challenge-response scheme, key-sharing scheme, etc.)

c) Name of certificate or the like for authentication (refer to the certificate/secret data corresponding to the authentication scheme).

In the mediation-service authentication information table 103 there are held such pieces of information as listed below.

[0090] a) Various certificates that are used for client authentication by the VPN client unit (SPKI certificate, PKI certificate, password, common key, etc.),

b) Certificates that are used for authentication of the mediating apparatus by the server (SPKI certificate, PKI certificate, password, common key, etc.)

In the tunneling/protocol configuration management table there are

held the following pieces of information for each tunnel to the VPN client unit.

a) IP address of the tunnel starting point (IP address given to the VPN client unit from the network).

5 [0091] b) Protocol of tunneling (IPsec tunnel mode, PPP over IPsec, etc.).

c) Authentication/encryption scheme (SPKI1 scheme, PKI scheme, challenge-response scheme, key-sharing scheme, etc.). The tunnel that is set up to the VPN gateway unit as the result of mediation service is of the key-sharing scheme.

10 d) Name of certificate or the like for authentication (refer to the certificate/secret data corresponding to the authentication scheme).

e) Common key and attribute information posted from the mediation service.

f) Name of VLAN to which the tunnel is connected. “Personnel Division VLAN” or “Accounting Division VLAN.”

15 [0092] g) Private IP address delivered to the VPN client unit (Selected from among addresses d) in the VLAN configuration management table).

In the VLAN configuration management table 1037 there are held the following pieces of information for each VLAN.

20 a) Name of VLAN (“Personnel Division VLAN” or “Accounting Division VLAN”).

b) Network configuration management information of VLAN.

i) IP addresses of gateway, DNS server, WINS server, etc.

[0093] ii) Routing information to be posted to VPN client unit.

25 c) Packet filtering condition (which limits accessible services)

d) Range of private IP addresses deliverable to VPN client unit.

The VPN gateway unit 103 provides a secure communication channel

to the mediating apparatus 104 by use of the mediation service management information table 1034 and the mediation-service authentication information table 1035, and issues a VPN access mediation request (steps S1-S3). For example, upon authentication of the VPN client unit 101, the mediating

5 apparatus 104 sends a VPN access mediation notice to the VPN gateway unit 103 (step S4). The notice information (IP address IPADDRESS\_A1 of the VPN client unit 101, common key KEY\_AB, attribute information ATTRIBUTE\_A1, etc.) is stored in the tunneling/protocol configuration management table 1036. Based on the attribute information, the VLAN 121  
10 to be accommodated is determined, and the VLAN name "Personnel Division VLAN" is also stored in this table (step S5). In this instance, the VPN client unit 101 is notified that it has the attribute information (VLAN Personnel Division) as shown in Fig. 20. Accordingly, it is determined that VLAN to accommodate the tunnel from the VPN client unit 101 is "Personnel Division  
15 VLAN."

[0094] Upon issuance of a VPN tunnel set-up request from the VPN client unit 101 (step S6), the VPN gateway unit refers to the tunneling/protocol configuration management table 1036 (step S7), then performs predetermined authentication/encryption, after which it refers to the VLAN configuration  
20 management table 1037 of the corresponding VLAN 121(step S8), then selects unused one of private IP addresses deliverable to the VPN client unit 101, and posts it to the VPN client unit 101, together with network configuration management information (addresses of the gateway, DNS, the WINS server, and so on). In this instance, the private IP address of the VPN  
25 client unit 101 is delivered from the address table of the personnel division VLAN. Also, network configuration management information on the gateway, DNS, etc. is posted from the personnel division VLAN.

[0095] Upon arrival of a VPN-destined data packet at the VPN gateway unit through the above-mentioned tunnel from the VPN client unit 101, it is subjected to filtering based on the filter condition of VLAN having accommodated therein the tunnel, thereafter being transferred to the VLAN (step S10). Besides, filtering for each tunnel may be additionally set using attribute information. Similar processing is also carried out for the request from the VPN client unit 102.

In the case of disconnecting the tunnel, the corresponding entry is removed from the tunneling/protocol configuration management table 1036, and the private IP address assigned to the VPN client unit is returned to an address pool of the VLAN concerned.

As described above, according to the present invention, the mediating apparatus stores information (access control list) that is used to establish a remote-access VPN by an arbitrary tunneling protocol, such as IPsec or L2TP, between each of the VPN client unit connected to the IP network and the VPN gateway unit, and an arbitrary communication unit connected to the local area network placed under the management of the VPN gateway unit. This information contains the private IP address assigned to the communication unit.

[0096] On receiving from the VPN client unit a request for retrieval of the IP address assigned to the VPN gateway unit, the mediating apparatus verifies whether the VPN client unit has a right to retrieve the IP address assigned to the VPN gateway unit. And, only when the VPN client unit has the right, the mediating apparatus refers to the access control list and acquires therefrom the private IP address assigned to the communication unit connected to the local area network placed under the management of the VPN gateway unit and the attribute information of the VPN client unit, then

searches the domain name server to obtain the IP address assigned to the VPN gateway unit, and generates the common key that is used for authentication by IKE or the like between the VPN client unit and the VPN gateway unit.

Then the mediating apparatus encrypts the communication channel between it

5 and the VPN client unit, and sends the IP address assigned to the VPN gateway unit, the private IP address assigned to the communication unit, and the common key to the VPN client unit over the encrypted communication

channel. Further, the mediating apparatus encrypts the communication channel between it and the VPN gateway unit, and sends the IP address

10 assigned to the VPN client unit, the generated common key, and the attribute information on the client unit to the VPN gateway unit over the encrypted communication channel. Incidentally, the host name in the DNS query of the VPM gateway unit may be regarded as a VPN portal service that is provided via the gateway unit, rather than a physical VPN gateway unit.

15 This service is provided from the communication unit having a private IP address. By giving multiple host names to one VPN gateway unit and entering them into DNS, it is possible to link multiple communication units having different private IP addresses. For example, when a customer-specific and an in-house communication unit are in the VPN placed  
20 under the management of the VPN gateway unit, a customer-specific and an in-house access units may be connected to the corresponding communication units, respectively, by giving different host names to them and managing them by different access control lists.

[0097] And, the mediating apparatus authenticates the VPN client unit and the

25 VPN gateway unit by the SPKI scheme. And the VPN client unit issues certificates by the SPKI scheme. Further, the mediating apparatus also enables authentication of the VPN client unit and the VPN gateway unit by

the PKI scheme.

Further, the mediating apparatus enables identification of the VPN client unit, the VPN gateway unit and the communication unit by arbitrary name formats such as public key, FQDN (Fully Qualified Distinguished  
5 Name), GUID (Globally Unique Identifier), MAC address, SPKI (Simple Public Key Infrastructure), Local Name, X.500 Distinguish Name, etc. This permits implementation of the remote-access VPN by a combination of IPsec, L2TP or arbitrary tunneling protocol and PKI, SPKI, password or arbitrary authentication scheme.

10 [0098] Needless to say, it is possible to carry out the present invention by programming the processing function of part or whole of each unit or apparatus in the systems of Embodiments 1 to 4 described above and by executing the program by a computer, or it is possible to program the procedures described with reference to Embodiments 1 and 2 and execute the  
15 program by a computer. The program for implementing the processing function by a computer, or a program for performing the processing function by a computer can be retained or dispensed by recording the program on a computer-readable recording medium such as, FD, MO, ROM, memory card, CD, DVD, removable disk, or the like; furthermore, the program can be  
20 distributed over the Internet or similar network.